



REVIEW / *Musculoskeletal imaging*

# A review of the value of MRI signs in low back pain



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## KEYWORDS

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**Abstract** Low back pain is a common symptom that can lead to disability and major socio-professional repercussions. Despite advances in imaging, the etiology of the pain often remains unknown. Morphological changes related to normal ageing of the disc appear on MR imaging without any symptoms. The potential impact of changes seen on imaging, especially MRI, also warrants discussion. The purpose of this work is to review the state-of-the-art of this subject, underlining relevant key features for routine radiological practice. We will first discuss anterior and posterior segments of the spine with a focus on anatomical, physiopathological and semiological findings. Secondly we will discuss the diagnostic value of each sign.

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Low back pain is a common symptom with considerable social and economic repercussions. When it lasts for less than a month, it is said to be acute, for between 1 and 3 months subacute, and beyond that, chronic.

In France, the prevalence of disabling low back pain is approximately 7 to 8% [1]. These cases are essentially 'common' low back pain of microtraumatic or degenerative origin, and are said to be non-specific. They differ from secondary or specific back pain, which has a number of different causes, and may be spinal or extra-spinal (infection, inflammation, tumor, trauma).

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If there are no worrying clinical criteria, the French *Haute Autorité de Santé* (National Health Authority) recommends no additional imaging examination before the 7th week for cases of common low back pain, i.e. where there are no signs of specific back pain. Standard radiography is the first examination to perform, with MRI or CT only used for further investigations [2]. Despite technical progress in imaging, the precise cause of the pain can only be determined in less than 50% of cases [3]. Several studies have shown that there is not necessarily any relationship between the severity of the lesions as seen in imaging and the intensity of the back pain [4–7]. The natural ageing of the disc as demonstrated in some subjects who feel no pain at all but which nevertheless appears as clear morphological changes in MRI, is the most eloquent example [8–13]. Conversely, it is common to find only minimal disc changes in imaging examinations in patients disabled by low back pain. These two observations thus raise the question of the value of MRI signs in low back pain. Despite the variability of the series available on the subject, with sometimes discordant results, this review of the literature aims to present the current state of knowledge on the subject and, where appropriate, to highlight the main points useful for good MRI practice.

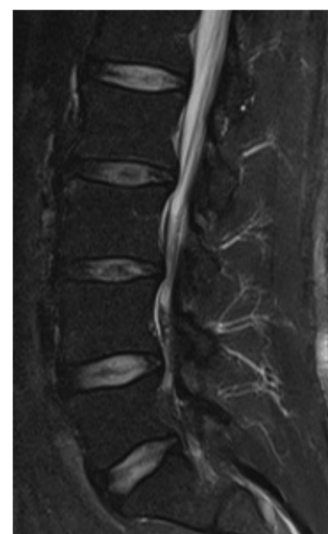
## Anterior segment

### Anatomical overview

Apart from around the periphery, the vertebral endplates are covered by hyaline cartilage that allows the exchange of a number of metabolites, such as water, glucose and oxygen, with the disc. The nucleus pulposus (NP) occupies about 50% of the central volume of the intervertebral disc (IVD). It is composed of chondrocytes and a loose network of collagen fibers, bathed in a proteoglycan matrix, largely responsible for hydration of the disc. This composition allows it to cushion shocks by compression [11] and explains the high intensity seen in MRI with T2-weighting. From 30 years of age, an intranuclear cleft corresponding to fibrous transformation may appear as a low intensity linear image in the center of the disc (Fig. 1) [14,15]. The peripheral annulus fibrosus (AF) seals the whole circumference of the disc. It is composed of a network of concentrically organized dense elastic collagen fibers, which explains its low MRI intensity [11,16]. Its most peripheral fibers, known as Sharpey's fibers, anchor the AF to the marginal border (edges of the vertebral endplates) and prevent the NP moving outwards.

### Physiology, signs and the prevalence of signs of degenerative disc disease in asymptomatic subjects

Where there is sometimes a genetic disposition, disc degeneration can be the result of disc ageing combined with microtraumatic and nutritional factors [17]. While it sometimes causes low back pain, this disc degeneration remains asymptomatic in a large number of cases [11]. It is expressed as 4 MRI signs which may occur together or separately and which we will describe in succession [16]: loss of intensity with T2-weighting and/or a reduction in disc height,



**Figure 1.** Sagittal STIR MR image shows linear hypointensity within the discs at several levels corresponding to physiological internuclear clefts that may be seen in patients over 30-years-old.

posterior high intensity of the disc, disc herniation, and endplate changes.

### T2-weighted low intensity and decreased disc height

Disc degeneration is characterized by a reduction in the production of proteoglycan, consequent disc dehydration and an increase in the collagen content of the NP, making it more fibrous [17,18]. The nucleus, which has become more solid, loses its elasticity and its shock-absorbing ability. The AF, which has to withstand more stress because of the reduced effectiveness of the NP, becomes less extensible, and its organization is modified by the formation of clefts. This is followed by disc collapse, sometimes contributing to the disc bulging beyond the intervertebral space, discussed below.

There have been many classifications of these modifications, although they are little used routinely, which do however remind us of the physiopathological cascade that leads to decreased intersomatic disc height (Table 1) [12,19].

These abnormalities are highly prevalent in asymptomatic subjects, with prevalence seeming to be relatively correlated to age: it has been estimated at between 36 and 85% between the ages of 20 and 80, with the last two lumbar levels clearly predominating [10,20,21]. While the degrees of disc degeneration are not much taken into account in the literature, so-called 'discreet' changes seem to be more common (26% to 100%) than 'moderate to severe' changes (35 to 72%) [10,12,13,22]. As an example, Malghem et al., studying 69 symptom-free patients (20 to 75 years of age), only observed disc modifications that were severe in one patient (1%), whereas they were considered moderate in 35% of the cases, even in young patients [10].

### Posterior high intensity of the disc

Ageing of the NP is expressed as concentric, transverse or radial fissuring. Posterior and radial fissuring is responsible

**Table 1** Degenerative disc changes classified with a grade [19] or stage [12] depending on the study.

Grade	Stage	Correlation of changes in MRI
Grade 1 and 2	Normal	Homogeneous T2-weighted high intensity or with a central low intensity line with T2-weighting with normal disc height
Grade 3	Discreet	Discreet reduction in T2-weighted intensity of the disc with normal disc height
Grade 4	Moderate	Clear T2-weighted low intensity of the disc and/or disc moderately decreased by less than 50%
Grade 5	Severe	T2-weighted marked low intensity of the disc and disc collapse

for posterior high intensity of the disc with T2-weighting, with median or paramedian topography, known as the high intensity zone (HIZ) (Fig. 2). Histological examination of the HIZ shows the presence of hypervascularized granulation tissue, which may be inflammatory, around the fissure, allowing the penetration of nuclear material [23]. In other words, this zone of fragility is a site for easy disc herniation beyond the intersomatic space, and is most common at L4-L5 and L5-S1, rarer at L2-L3 and exceptional at L1-L2 [13,24].

In asymptomatic subjects, its prevalence varies between 12 and 56% [12,25] and increases with age [12]. In the study by Stadnik et al., concerning 36 asymptomatic volunteers, 11% of the subjects less than 30-years-old had a zone of

T2-weighted high intensity, whereas such a zone was found in 100% of the subjects over 61 years of age. Overall, it was shown by a little more than one subject in two [12].

### Disc herniation

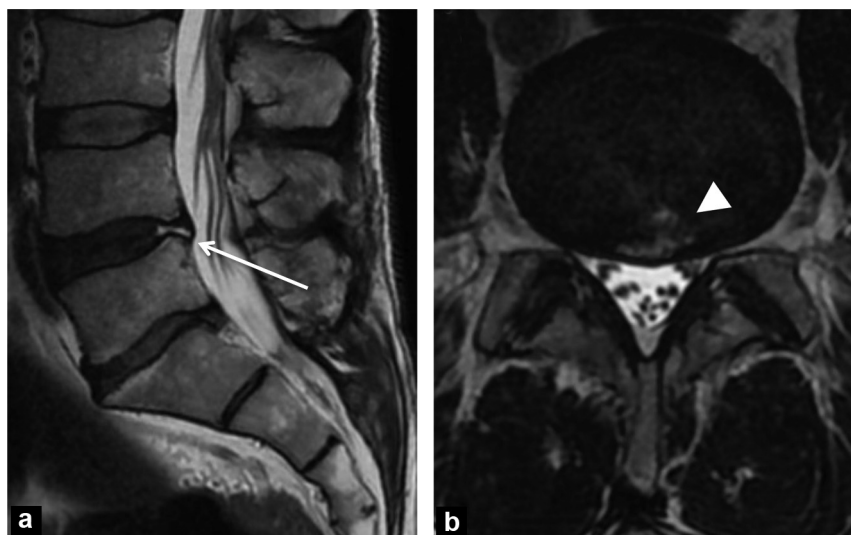
Discs herniating to the exterior are classified by their global or more focal, circumferential extension, and their actual morphology when they are focal. The consensus concerning these appearances has been used here (Fig. 3) [26].

*Global disc bulging* (or *spreading*) is defined as the disc protruding beyond the margins of the vertebral endplates over more than 50% of their circumference [26]. It is usually accompanied by a loss in disc height and is present in 15 to 81% of asymptomatic subjects [12,25].

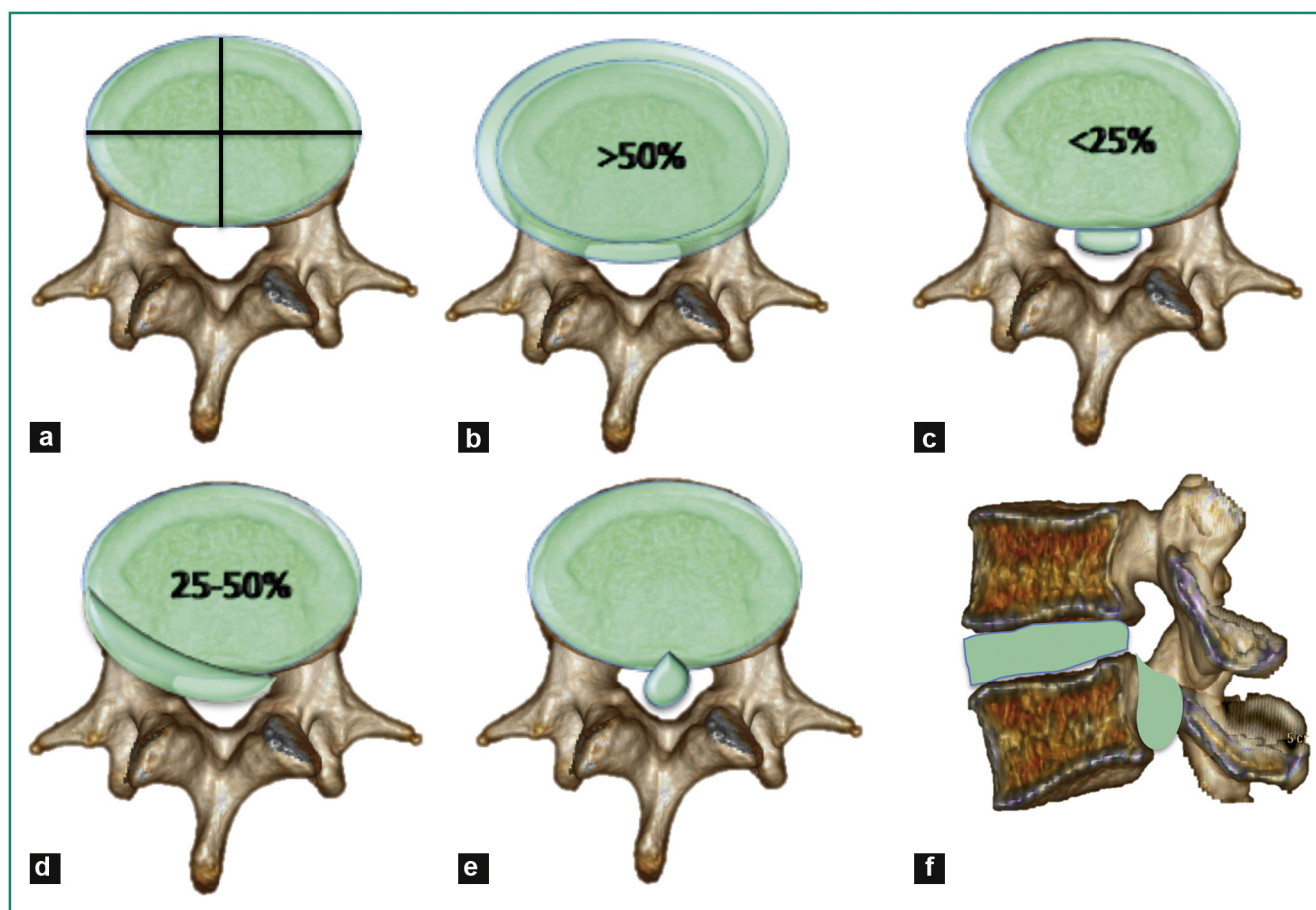
A *herniated disc* differs from a bulging disc by being local, the protrusion of disc material occurring focally through a point of fragility in the annulus [16]. It is defined by its size, position and shape, and can be median (10%) posterolateral (80%), foraminal, extraforaminal (10%) or anterior (rare) [6,16].

Disc hernias have been classified into three types depending on their shape [26]:

- **protrusion disc herniation:** this is focal herniation where the base is wider than the other dimensions. A few fibers of the fibrous ring have ruptured. The hernia may be narrow based, extending over less than 25% of the circumference of the disc, or broad-based when extending over 25 to 50% of its circumference [26]. It is frequently found in asymptomatic subjects, with a prevalence of 20 to 63% [8–10,12,22,25];
- **extrusion disc herniation:** this is focal herniation where the base is narrower than the body. All the fibers of the AF have ruptured. This type of hernia is rarer in asymptomatic subjects, with prevalence found to be between 0 and 24% of cases [8–10,12,21,22,27];
- **sequestration disc herniation:** in this case, there is loss of continuity with the disc. A hernia which has migrated by more than 6 mm upwards and 12 mm downwards has a



**Figure 2.** a: sagittal T2-weighted MR image; b: axial T2-weighted MR image of the L4-L5 disc, showing an area of high signal intensity (arrow) within the posterior annulus of the disc corresponding to radial annular disruption (arrow head).



**Figure 3.** Classification of bulging disc and disc herniation: a: normal disc; b: bulging disc (presence of more than 50% of the circumference of the disc tissue beyond the edges of the intervertebral ring apophyses); c: focal protrusion (of less than 25% of the disc circumference); d: broad-based herniation (between 25 and 50% of the disc circumference); e: extrusion (the greatest cranio-caudal diameter of the fragment is greater than the cranio-caudal diameter of its base); f: sequestration (sequestered fragment).

considerable likelihood of sequestration [28]. This type is not found in asymptomatic subjects [9,10,13].

An *intravertebral hernia* (*Schmorl's nodule*) is a different entity. It is the migration of a disc fragment through areas of weakness in the vertebral endplate (Fig. 4) [26]. Its exact origin is a source of controversy. It is sometimes found in a traumatic setting, often with an axial load [29–31] or in other situations where the vertebral endplate is weakened (Scheuermann's disease in adolescents, osteoporosis in older people) [30]. Its prevalence in MRI is 19 to 24% in asymptomatic subjects [9,10].

### Vertebral endplate changes

In one MRI study in 474 patients with low back pain, Michael Modic described endplate signal changes in disc degeneration, divided into three grades (Fig. 5):

- Modic type 1 changes: changes with an edematous appearance, hypointense on T1-weighted images and hyperintense on T2-weighted images, with enhancement after gadolinium injection;
- Modic type 2 changes: fatty changes, hyperintense on T1-weighted images and hyperintense on T2-weighted images (or hypointense with T2-weighting and FatSat);

- Modic type 3 changes: fibrous/osteosclerotic changes, hypointense on both T1 and T2-weighted images.

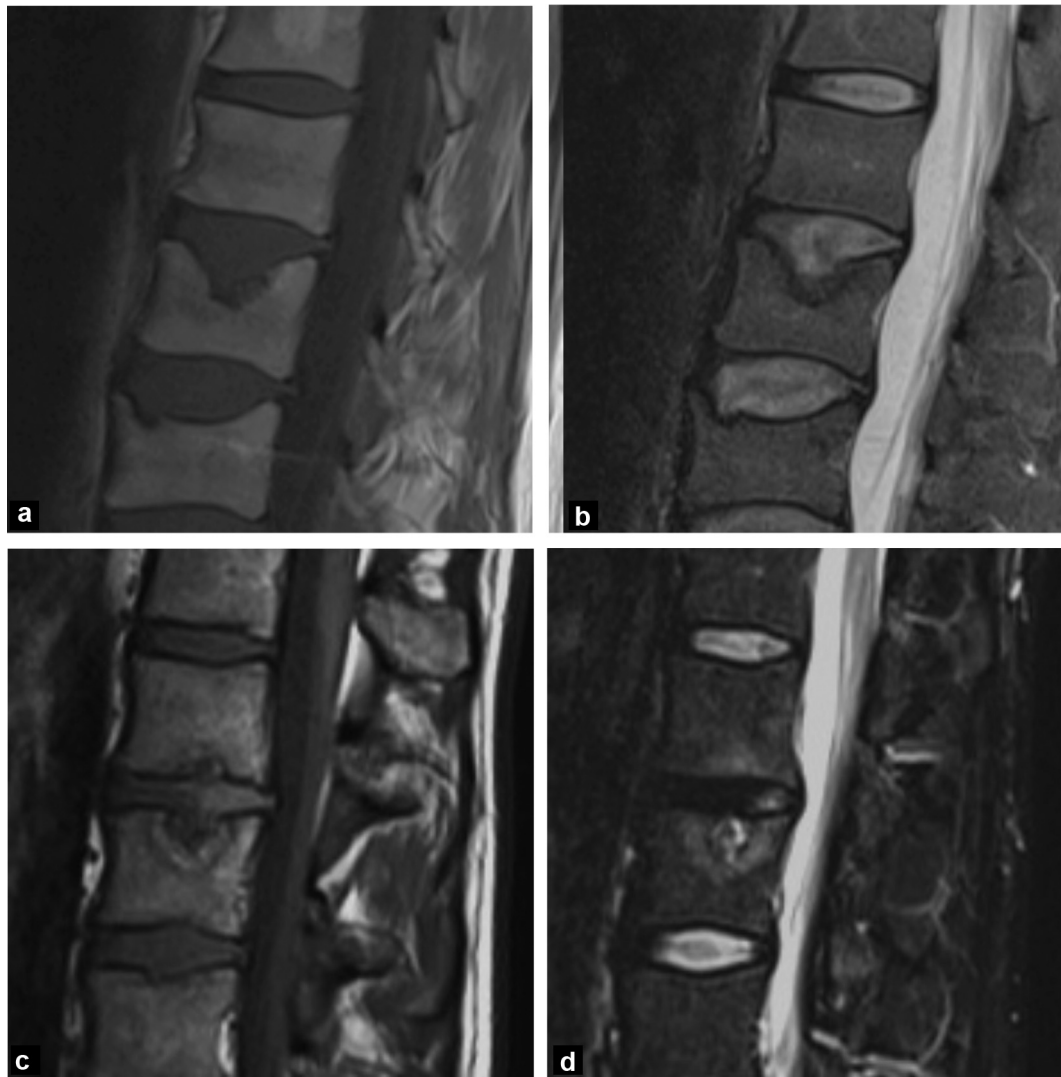
The etiology and physiopathology of Modic 1 is still unknown. There seems to be an association between mechanical, microtraumatic and biochemical processes secondary to the increase in subchondral strains in the endplates responsible for microfractures.

Mixed forms have been described with Modic type 1 and 2 or Modic type 2 and 3 changes coexisting on the same vertebral endplate which, for certain authors, suggests the possibility of progression from one type to another in a given patient [32,33]. Type 1 may be stable, become normal, or aggravated or evolve into type 2. Type 2, for a long time considered stable, can evolve into type 1 [34,35]. Type 3, which is very rare, is the ultimate stage of endplate condensation.

Types 1 and 2 are chiefly located in the anterior third of the vertebral bodies in the last two levels of the lumbar spine [25,34].

There are not many studies on asymptomatic subjects: they report prevalence of 0 to 13.5% for Modic type 1 changes, 3 to 25% for type 2, while type 3 does not exist [10,13,25]. The prevalence of these changes increases with age. Modic type 1 and 2 changes do not exceed 3 to 10% before 50 years of age, but rise to 20% after the age of 50





**Figure 4.** a, c: sagittal T1-weighted MR images and b, d: sagittal STIR MR images: a and b: intervertebral herniation is seen in the vertebral body of L2; c and d: intervertebral herniation in the L2 vertebral body with high signal intensity, on STIR MR images, adjacent to the herniation.

[10,13]. Modic type 2 changes are indeed three times more common than type 1 changes.

## Posterior segment

### Anatomical overview

The posterior facet joint is a synovial joint formed by the posterior articular facets of two adjacent vertebrae. It is covered by a capsule strongly innervated by the medial rami of the posterior branches of the spinal nerves and can be a source of pain when stretched or irritated. These rami also have collaterals (particularly muscular sensory collaterals) [36]. This anatomy may explain why facet joint arthritis is associated with paravertebral muscular contraction. The facet joints are oblique inferiorly, posteriorly and laterally and play an important role in the transmission of loads and the stabilization of segments during flexion/extension movements, and limit axial rotation [37,38]. Within a lateral

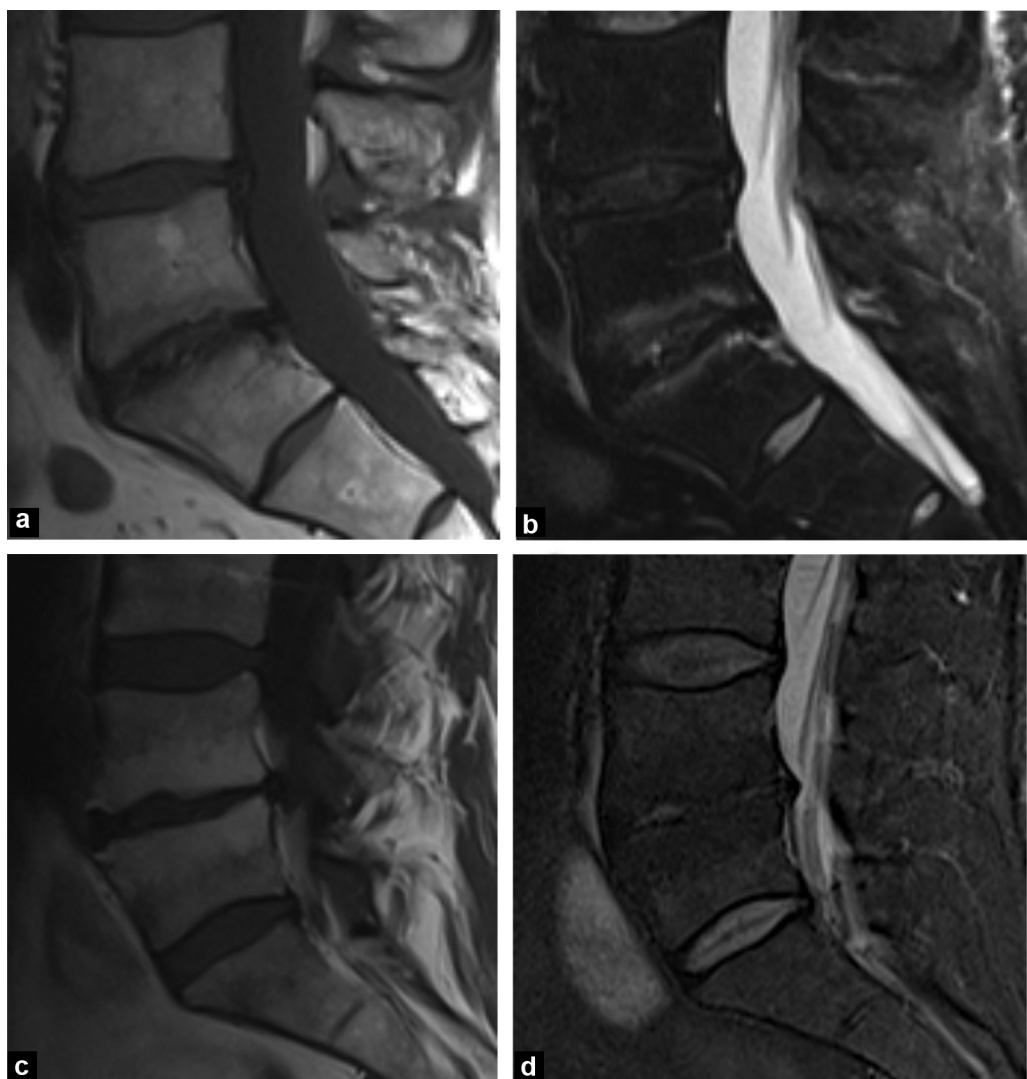
mass, the isthmus or pars interarticularis is the junction between the superior and inferior articular masses.

### Conditions and prevalence in asymptomatic subjects

#### Posterior facet joint arthritis

Cranio-caudal facet joint subluxation during movement is the cause of degenerative changes, which are summarized in Grogan's classification, although this is not used on a routine basis [39]. It evaluates, in MRI, the severity of degeneration, based on cartilaginous damage (thickness and bone coverage), subchondral sclerosis (thickening of the cortical bone) and the presence of osteophytes, in four grades. To these are added the presence of an intra-articular effusion, edematous areas within the bone and peri-articular soft tissue [40], visible with MRI (Fig. 6).

Facet joint arthritis occurs predominantly at L4-L5, where the very sagittal orientation of the articular processes



**Figure 5.** Sagittal T1-weighted MR images (left) and sagittal STIR MR images (right): a and b: low signal intensity (SI) on T1-weighted images and high SI on STIR images of the endplates at L5-S1 related to a type I endplate change; c and d: high signal intensity on T1-weighted images and low signal intensity on STIR images of the endplates at L4-L5 related to type II endplate change.

makes them more unstable than at L5-S1. Its prevalence in asymptomatic subjects is high in CT scans, estimated to be between 64 and 67%. It is less easily evaluated with MRI where the figures reported fluctuate between 3 and 18% [9,13,41,42]. It increases with age and becomes commonplace after 45–50 years of age [41–45].

### Interspinous bursitis

Interspinous bursitis, in the context of degenerative phenomena (Baastrup disease), is a synovial neoarticulation secondary to decreased disc height and repeated friction movements between the spinous processes (Fig. 7). It is encouraged by hyperlordosis, anterolisthesis, decrease in the intersomatic spaces and severe degenerative phenomena. Visible with MRI as an increased interspinous signal on T2-weighted images and decreased signal on T1-weighted images, it often occurs at several levels, predominantly at L4-L5, and increases with age [46]. No prevalence in asymptomatic subjects is reported in the literature.

### Degenerative spondylolisthesis

Spondylolisthesis results from the displacement of the superior relative to the inferior vertebral body due to degenerative sagittalization of the articular facets [47]. Most often the displacement is anterior and may include a certain degree of rotation. The Meyerding classification describes four grades on sagittal images. The vertebral plate is divided into four quarters and the slip is assessed depending on the position of the tangent to the posterior edge of L5. Grade I is a slip of less than 25%, grade II between 25 and 50%, grade III between 50 and 75%, grade IV between 75 and 100% and grade V is spondyloptosis.

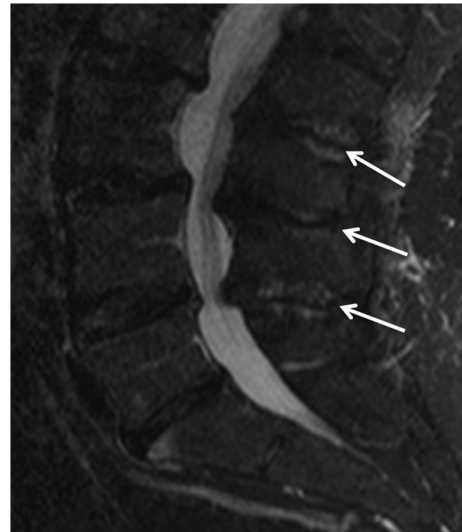
It most often occurs at L4, predominantly in women, and is encouraged by lumbar hyperlordosis and being overweight [48].

### Spondylolysis

Spondylolysis is a stress fracture of the isthmus and may be unilateral or bilateral [49]. When it is bilateral, it can also



**Figure 6.** Parasagittal STIR MR image. Modic type 1 pedicle marrow signal intensity changes on L5 and S1 (arrow) and hyperintensity within the soft tissues adjacent to the facet joints at both levels (arrow head) associated with degenerative facet disease.



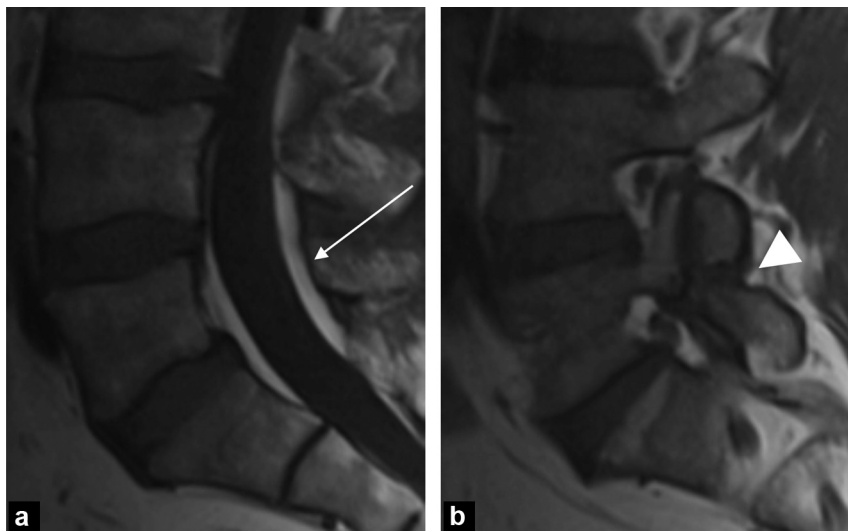
**Figure 7.** Small interspinous bursitis (arrows) with high signal intensity on STIR MR image in a degenerative disc context.

lead to spondylolisthesis. Rarely, the fracture may be acute and traumatic or, more often, result from repeated micro-traumas. It occurs predominantly at L5 (85 to 90%) where the morphology of the isthmus exposes it to a nut-cracker effect between the superjacent and subjacent articular processes in extension. Direct visualization of the fracture is sometimes difficult with MRI in the sagittal plane due to partial volume effects on this narrow anatomical structure. The indirect signs of fracture include cancellous edema of the isthmus and the presence of epidural fat between the posterior dural layer and the anterior part of the spinous process of the vertebra on a median sagittal slice (Fig. 8), secondary to enlargement of the central canal. The specificity of this indirect sign, described by Sheriff et al., is 96.7% and its sensitivity, 78.8% [50].

In MRI, spondylolysis can be divided into 4 grades according to Hollenberg et al. [51]:

- grade 1 (stress reaction): isthmic edema with or without edema of the pedicle or adjacent joint but without any cortical abnormality;
- grade 2: isthmic edema associated with incomplete fracture of the isthmus;
- grade 3: isthmic edema with complete fracture of the isthmus;
- grade 4: complete fracture of the isthmus without edema.

Isthmic fracture and/or the consecutive spondylolisthesis affects about 7 to 8.5% of asymptomatic patients and increases with sporting activities [9,49,52–54].



**Figure 8.** Sagittal T1-weighted MR image: a: interposition of epidural fat between the dura mater and the spinous process of L5 (arrow); b: fracture of the L5 pars interarticularis (arrow head).

## The value of MRI signs

The sometimes high prevalence of some of these signs in the spines of asymptomatic subjects raises the question of their value in subjects in pain. We therefore understand the radiologist's necessary caution when producing a radiological report and interpreting the MRI where there is low back pain.

Despite the often contradictory data, a few signs seem to be predictive of low back pain, at least regarding the populations studied.

### Anterior segment

#### Vertebral endplate changes

Of all the radiological signs for the anterior segment, the main one, which has a recognized predictive value for pain, is a Modic type 1 change, in particular in subjects less than 50 years old. Its prevalence is higher in symptomatic patients (19 to 50%) than in asymptomatic subjects (0 to 13.5%) [27,55,56]. In a retrospective study of 2457 discs of symptomatic patients using provocative discography as a reference examination, the positive predictive value (PPV) of Modic type 1 changes was 81% with specificity of 98% [57]. Weishaupt et al. found that the severity and extent of Modic type 1 changes had a high predictive value for pain across the population studied (mean age: 42 years old;  $n=50$ ) [27]. In addition, Hancock et al. reported increased likelihood (estimated at 32) in the case of Modic type 1 changes extending over more than 25% of the height of the vertebral body, meaning that it is 32 times more likely that these signs will be present when an individual has low back pain than when he or she does not [58]. In a longitudinal follow-up, Mitra et al. showed a correlation between the favorable evolution of low back pain and the transformation of Modic type 1 into Modic type 2 changes, highlighting the probable continuum between these two entities [59]. In a population with chronic, disabling, low back pain, Modic type 1 disc disease was associated with an inflammatory pain rhythm, unlike a Modic type 2 picture [60]. To close the section on changes to endplate signals, it should be emphasized that bone edema peripheral to intracancellous hernias is also correlated with low back pain [61–63].

#### Decreased disc height, dehydration and a bulging disc

Initially, disc degeneration comprises loss of disc height, T2-weighted low intensity and a bulging disc. While the negative predictive value of these aspects for disc degeneration is high (98%), meaning that their absence makes it unlikely that there will be pain arising from the disc, their PPV and their specificity remain modest even when using grades 3 and 4 of the Pfirrmann classification [27]. Hancock et al. reported a positive but low likely relationship from Pfirrmann grade 3 (between 2.8 and 5.7), still considerably lower than the PPV for Modic type 1 changes [58].

#### Herniated disc

While the frequency of small hernias (less than 5 mm) is high in asymptomatic subjects, the frequency of larger

hernias, extrusions and sequestrations remains low, almost non-existent [8–10]. The presence of extrusion or sequestration hernias or disc/root conflict is correlated with root pain but not with low back pain [7].

### The HIZ

The involvement of the HIZ in pain would fit with our mind-set because we know that the posterior and posterolateral parts of the disc are richly innervated. However, the value of the HIZ is still very controversial, for its prevalence in subjects with low back pain varies between 28 and 59% with very varied values for sensitivity (27 to 81%), specificity (79 to 97%) and PPV (53 to 95%), depending on the series [24,64–68]. This high variability probably results from the heterogeneity of the populations studied, the size of samples or acquisition parameters and from the inclusion of posterolateral or lateral HIZs. While the sign's predictive value for low back is at the very least uncertain when it is in isolation, better performance has been suggested in association with a disc protrusion (Odds Ratio = 36.3 [8.2–161.1]) [64]. This study, alone in defending this association, suffers from small numbers and only concerns patients with very marked symptoms, candidates for arthrodesis. In contrast, the study by Standik et al. showed that an HIZ in asymptomatic subjects is often combined with disc protrusion [12]. As for Mitra, he did not show any concordance between the development of HIZs and the development of low back pain [69].

### Posterior segment

The prevalence of facet joint arthritis in symptomatic subjects varies between 12 and 61% depending on the series [58]. Because of its high prevalence in asymptomatic subjects, we know its low positive predictive value in CT scans [41]. Like Modic type 1 images of the endplates, T2-weighted high intensity of the articular facets may be correlated with pain and is found in at least 14% of patients with low back pain [40,70].

Interspinous bursitis is uncommon but not rare, found in 8.2% of symptomatic subjects [46]. Its role in low back pain is still controversial, because it is often combined with other degenerative phenomena. It is nevertheless important to describe it because in certain cases, it can be treated by local corticosteroid infiltration.

Degenerative or isthmus spondylolisthesis can indicate spinal instability (segmental hypermobility), which may require surgical treatment. An MRI, performed in the decubitus position, may minimize the displacement. MRI correlation between the size of the intra-articular effusion (>1.5 mm thick) and the presence of spondylolisthesis at L4-L5 has been reported, sometimes only visible on dynamic X-ray images performed in addition [71,72].

Finally, T2-weighted high intensity of the pedicle observed in fractures of the isthmus, more often found in adolescents, may signal the cause of the pain. If this sign persists in cases of low back pain, the treatment may need to be modified [40,73].



## Conclusion

This review underlines the high prevalence of asymptomatic spinal changes and the low predictive value of signs in low back pain. Without being pathognomonic, only Modic type 1 changes and intense, extensive zygapophyseal edematous changes seem to be relatively correlated with low back pain in a study population. Unfortunately, even these signs have a relative value on the individual scale, which requires systematic clinical/radiological correlation. Given the psychosocial impact of medical pronouncements and the radiological report for patients in chronic pain, it seems to us to be useful for the radiologist to have in-depth knowledge of the value of these signs. At the same time it will allow him to provide information useful to the clinician and help him give clear information to the patient.

## Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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